Step 5. Flood Module

Step 5. Flood Module

- Accounts for a reduction in flood damage costs
- Requires at least 3 sets of data

Average Daily Streamflow (cfs)	Return Period (years)	Flood Related Damages ($)

- Calculates: Annualized Loss = 1/Return Period × Flood Damage Costs
- Compares daily flow to flood flow range and if ….

  < smallest flood flow = $0
  smallest to largest flood flow = linearly interpolate for damages
  > largest flow = constant at largest flood damage

Flood Module, cont

- Limitations
  - Input requires DAILY flow not peak flow
    - United States Geological Service (USGS) PeakFQ and state-level regression equations provide peak flows
    - USGS streamflow gages provide average daily flows
  - Flood flow must occur during modeled time period
    - Check streamflow without flood module
    - Check precipitation record to identify wet years to model
  - Multiple, consecutive flood flows → may overestimate avoided damages

3

Overview

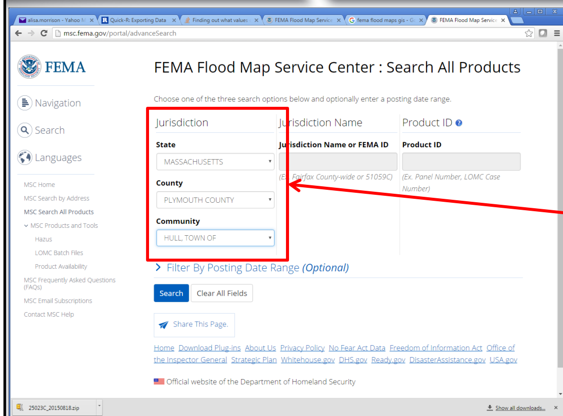
- **To create a damage curve**
  - **Create a flood depth grid**
    - **Using Arc GIS and FEMA data**
    - **Using Valley Floor Mapper software**
    - **Using default data**
  - **Create a site specific building inventory**
    - **Using user supplied data**
  - **Use HAZUS to determine flood damage levels**
    - **Using user defined flood grid**
    - **Using default parameters**

Developing the Flood Depth Grid

Flood Grid Mapping

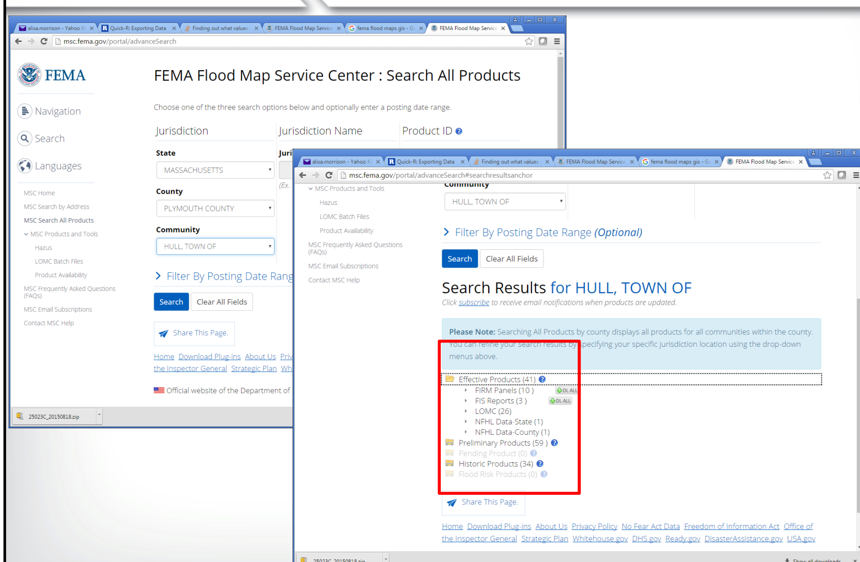
- **Data Needed for Flood Mapping**
  - **FEMA National Flood Hazard Layer (NFHL) data**
    - **Data can be downloaded for the entire state (where available) or by county. (https://msc.fema.gov/portal/advanceSearch)**
  - **HAZUS download (http://msc.fema.gov/portal/resources/hazus)**
  - **Elevation data-**
    - **National Elevation Data (NED) can be obtained at the National Elevation Dataset from the National Map. (http://viewer.nationalmap.gov/viewer/)**
    - **LiDar data can be found and downloaded from NOAA Digital Coast website (http://coast.noaa.gov/digitalcoast/data/coastallidar) or from state specific GIS websites where available.**

Downloading NFHL Data

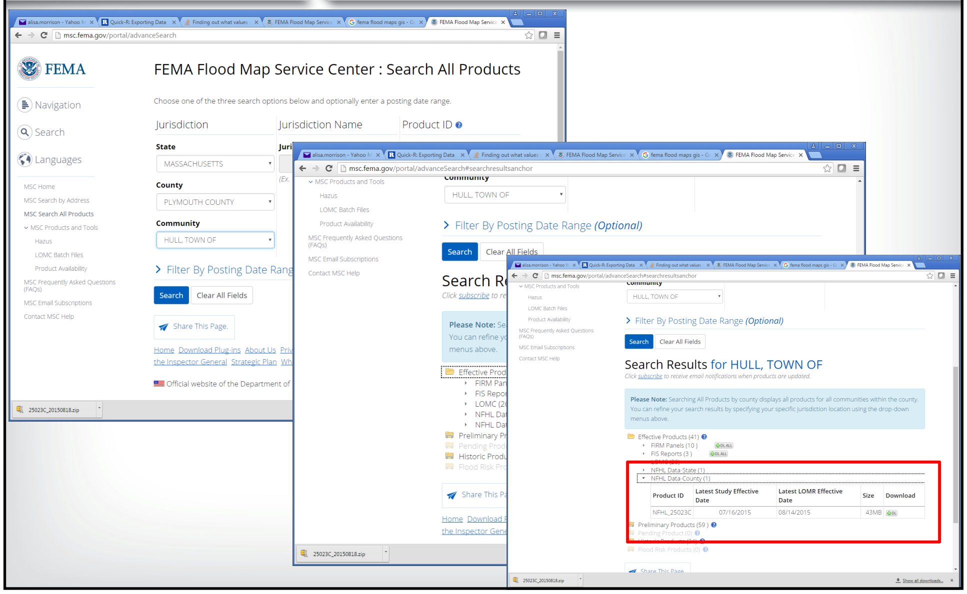


- Input search criteria
  - State, County, Community

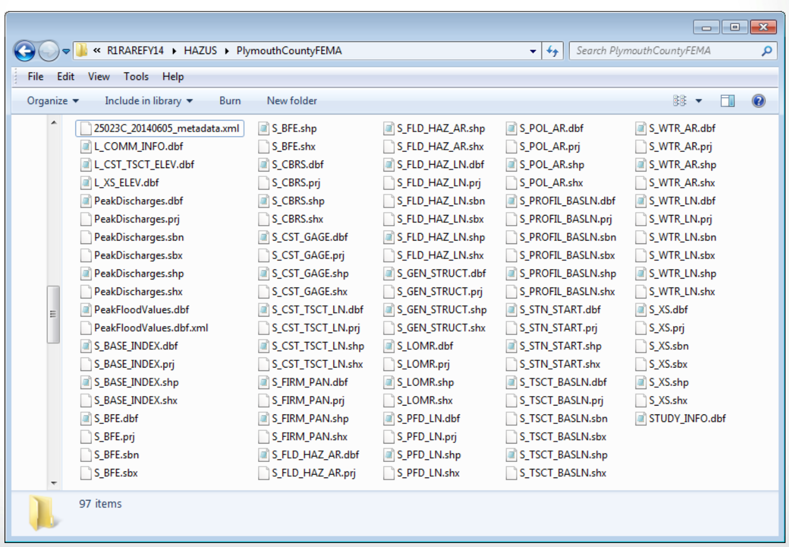
Downloading NFHL Data



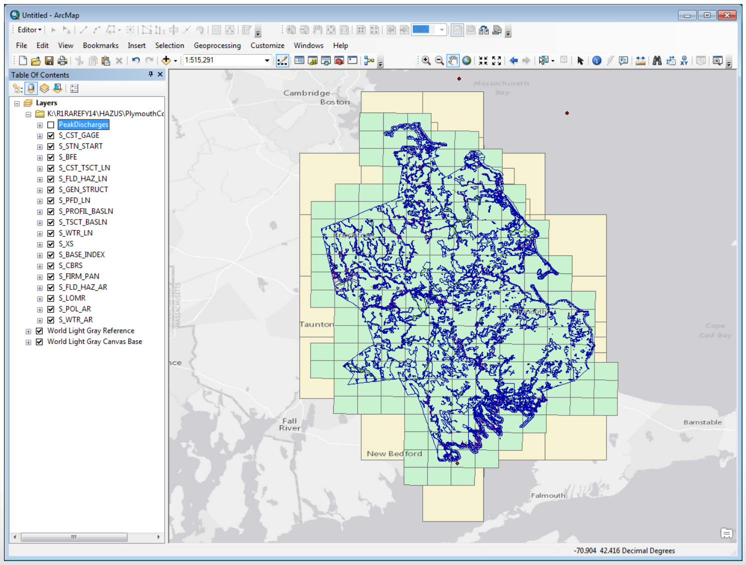
Downloading NFHL Data



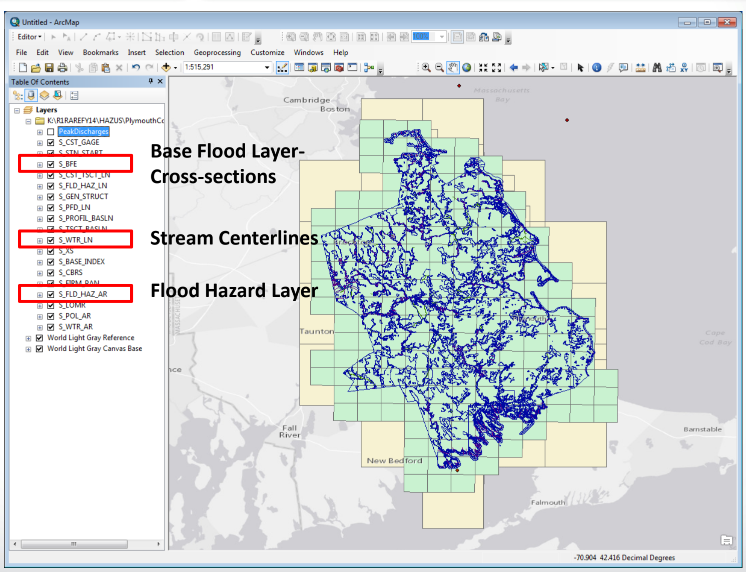
Downloading NFHL Data



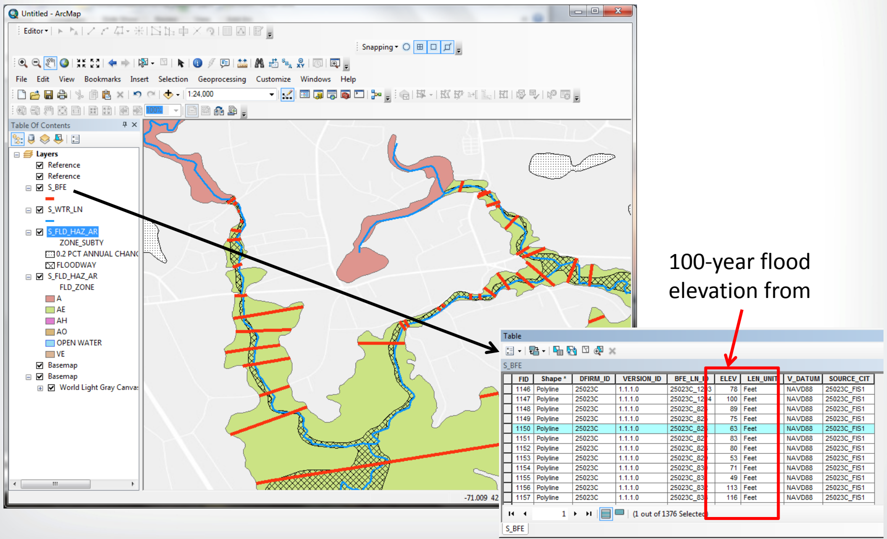
Downloading NFHL Data



Creating Flood Depth Grid

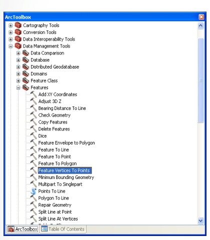


Creating Flood Depth Grid

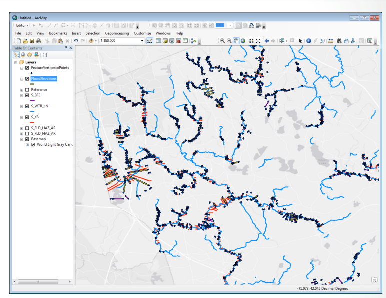


100-year flood elevation from

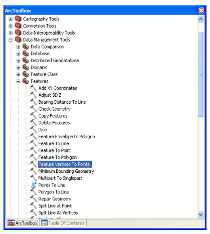
Creating Flood Depth Grid



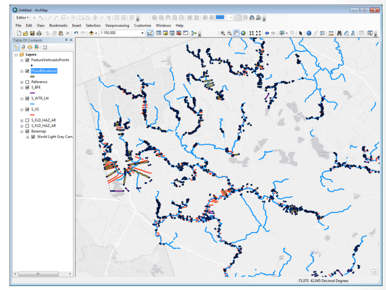
Create points at the end of each of the cross-section lines

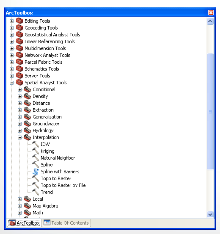


Creating Flood Depth Grid

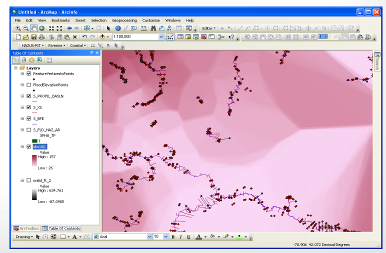


Create points at the end of each of the cross-section lines

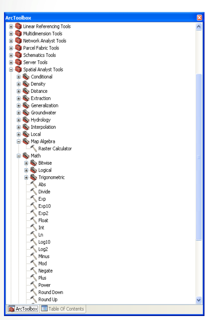


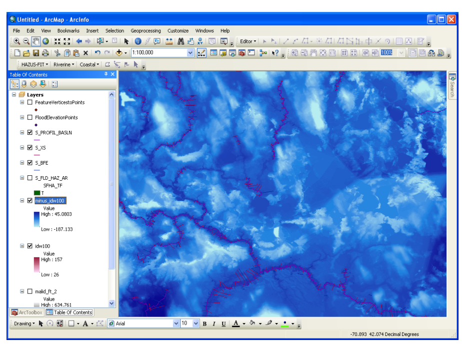


Use Inverse Distance Weighting (IDW) to create the flood grid using Elevation attribute



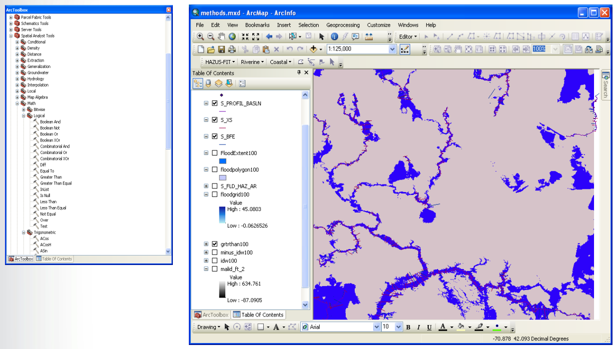
Creating Flood Depth Grid





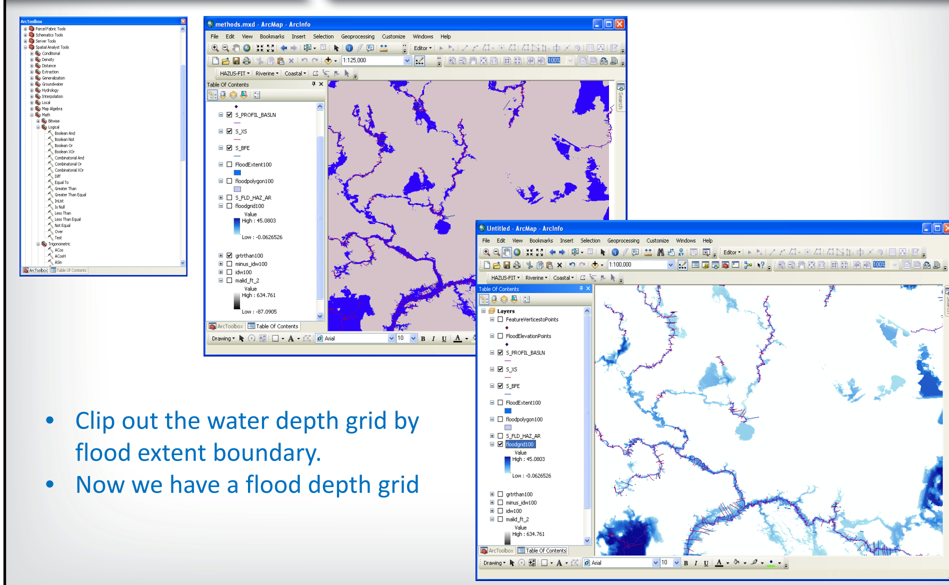
- Subtract the ground surface elevation (DEM) from the flood surface layer to determine a water depth grid.
- The resulting water depth grid will have negative values where the ground surface is above the flooded elevation (areas of no flooding) and positive values in flooded areas

Creating Flood Depth Grid



- Eliminate negative values using a conditional statement (Spatial Analyst>>Math>>Logical>>Greater than Equal).
- Now we have a polygon with the extent of the 100-year flood

Creating Flood Depth Grid

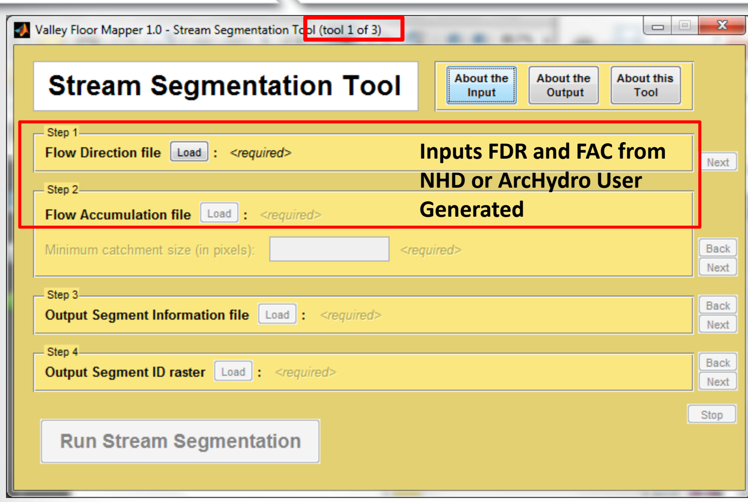


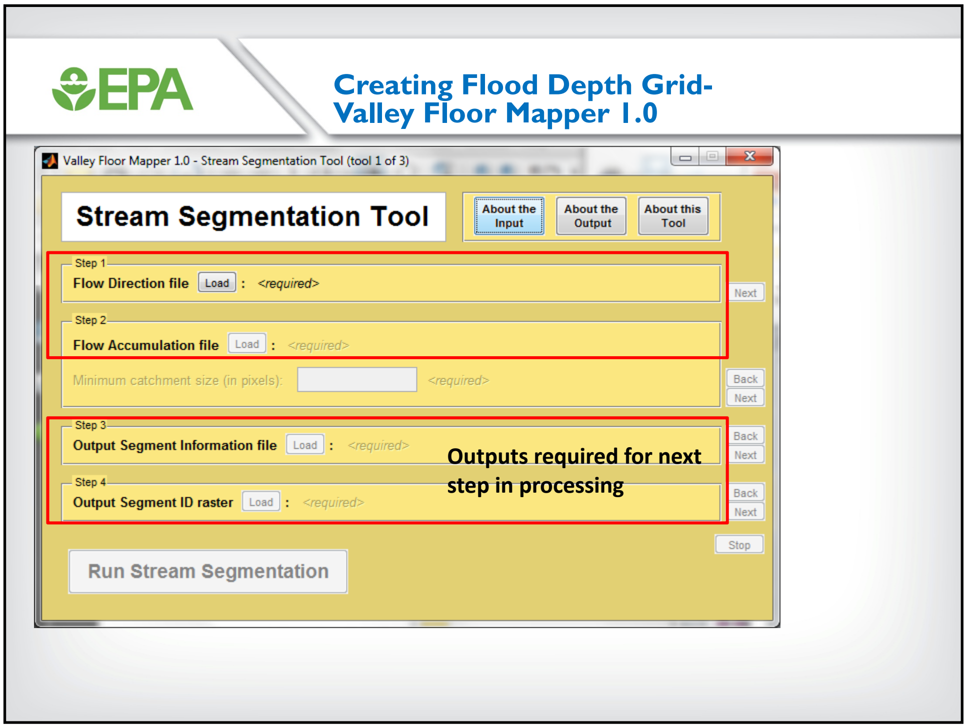
- Clip out the water depth grid by flood extent boundary.
- Now we have a flood depth grid

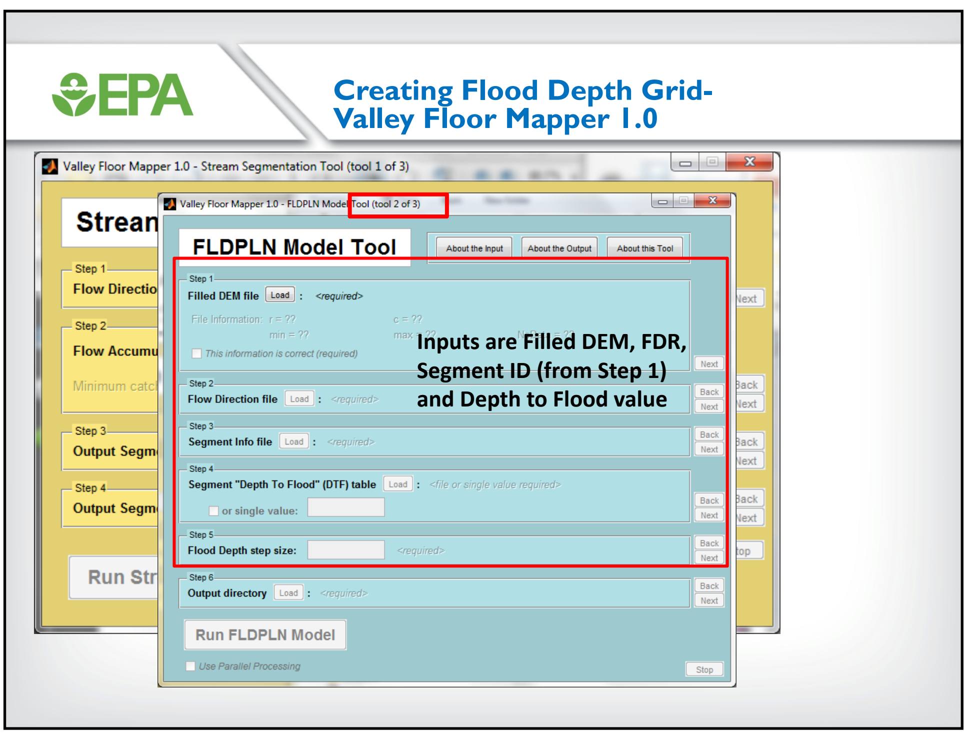
Creating Flood Depth Grid- Valley Floor Mapper 1.0

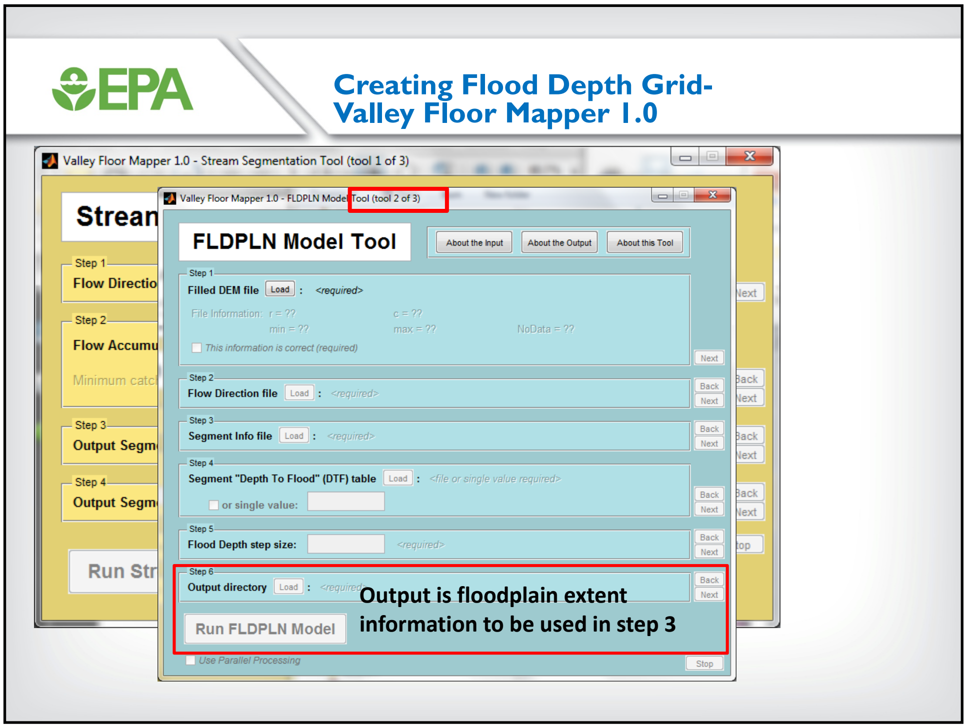
- **Valley Floor Mapper**
  - Developed by MACRO (Macroecogical Riverine Synthesis) and part of the RESonate Tool
  - Automated GIS-based process designed for ArcGIS that enables the processing of GIS data sources using freely available geospatial datasets. (http://www.macrorivers.org/resonate-model/)
- Input required
  - Flow direction grid (FDR) and Flow Accumulation Grid (FAC) available nationwide from NHDPlus (http://www.horizon-systems.com/nhdplus/NHDplusV2_data.php)
  - Digital Elevation Model (DEM)
  - Depth to Flood
    - User can specify constant value or input table of flood depths per stream segment

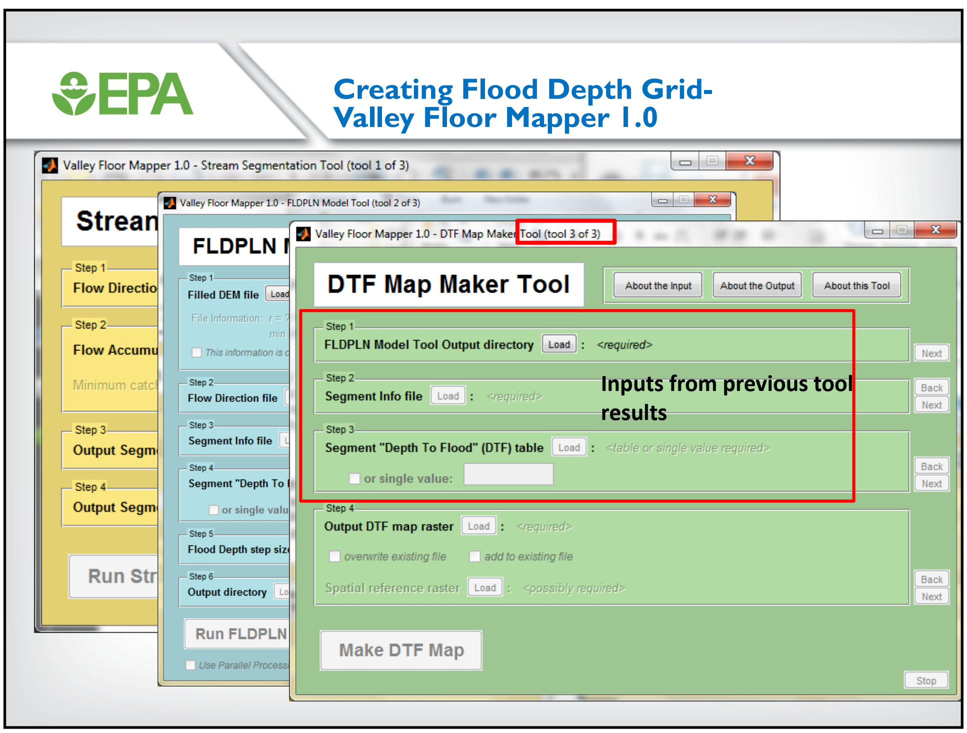
Creating Flood Depth Grid- Valley Floor Mapper 1.0



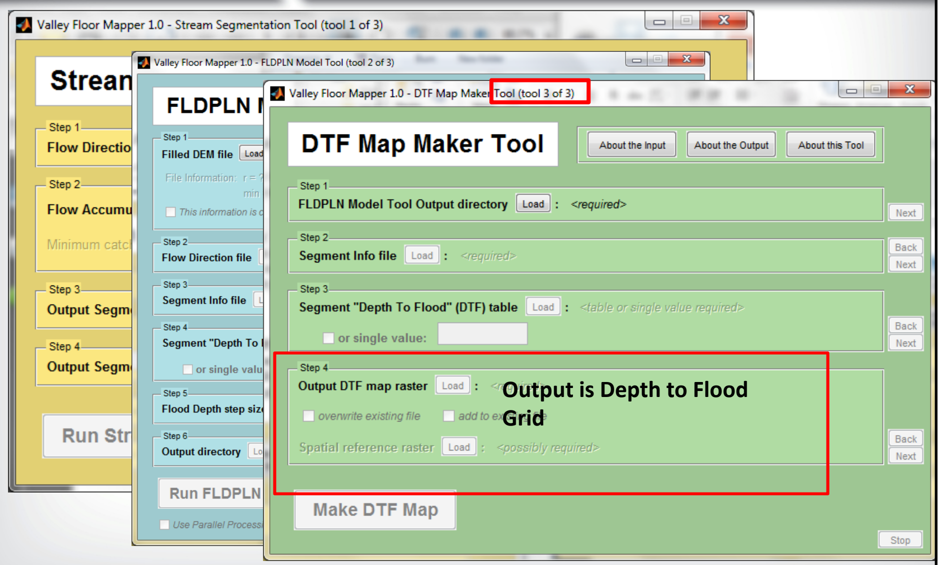

EPA
Creating Flood Depth Grid-
Valley Floor Mapper 1.0
Valley Floor Mapper 1.0 - Stream Segmentation Tool (tool 1 of 3)
Stream Segmentation Tool
About the Input
About the Output
About this Tool
Step 1
Flow Direction file Load : <required>
Step 2
Flow Accumulation file Load : <required>
Minimum catchment size (in pixels): <required>
Step 3
Output Segment Information file Load : <required>
Step 4
Output Segment ID raster Load : <required>
Outputs required for next step in processing
Back
Next
Stop
Run Stream Segmentation


EPA
Creating Flood Depth Grid-
Valley Floor Mapper 1.0
Valley Floor Mapper 1.0 - Stream Segmentation Tool (tool 1 of 3)
Valley Floor Mapper 1.0 - FLDPLN Model Tool (tool 2 of 3)
FLDPLN Model Tool
About the Input
About the Output
About this Tool
Step 1
Filled DEM file Load : <required>
File Information: r = ?? c = ??
min = ?? max = ??
This information is correct (required)
Step 2
Flow Direction file Load : <required>
Step 3
Segment Info file Load : <required>
Step 4
Segment "Depth To Flood" (DTF) table Load : <file or single value required>
or single value:
Step 5
Flood Depth step size: <required>
Step 6
Output directory Load : <required>
Inputs are Filled DEM, FDR, Segment ID (from Step 1) and Depth to Flood value
Run FLDPLN Model
Use Parallel Processing
Stop


Creating Flood Depth Grid-
Valley Floor Mapper 1.0
Valley Floor Mapper 1.0 - Stream Segmentation Tool (tool 1 of 3)
Valley Floor Mapper 1.0 - FLDPLN Model Tool (tool 2 of 3)
FLDPLN Model Tool
About the Input
About the Output
About this Tool
Step 1
Filled DEM file
Load
<required>
File Information: r = ??
c = ??
min = ??
max = ??
NoData = ??
This information is correct (required)
Step 2
Flow Direction file
Step 3
Segment Info file
Step 4
Segment "Depth To Flood" (DTF) table
<file or single value required>
or single value:
Step 5
Flood Depth step size:
Step 6
Output directory
Output is floodplain extent information to be used in step 3
Run FLDPLN Model
Use Parallel Processing
Stop


Creating Flood Depth Grid-
Valley Floor Mapper 1.0
Valley Floor Mapper 1.0 - Stream Segmentation Tool (tool 1 of 3)
Valley Floor Mapper 1.0 - FLDPLN Model Tool (tool 2 of 3)
Valley Floor Mapper 1.0 - DTF Map Maker Tool (tool 3 of 3)
DTF Map Maker Tool
About the Input
About the Output
About this Tool
Step 1
FLDPLN Model Tool Output directory
Load
<required>
Step 2
Segment Info file
Inputs from previous tool results
Step 3
Segment "Depth To Flood" (DTF) table
<table or single value required>
or single value:
Step 4
Output DTF map raster
overwrite existing file
add to existing file
Spatial reference raster
<possibly required>
Make DTF Map
Stop

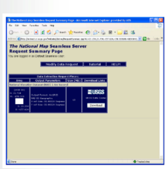
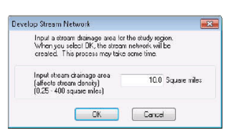
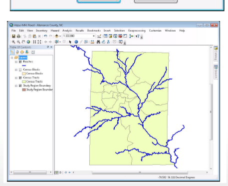
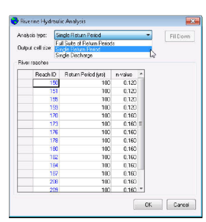
Creating Flood Depth Grid- Valley Floor Mapper 1.0



Creating Flood Depth Grid- HAZUS Default Values

- HAZUS default flood grids

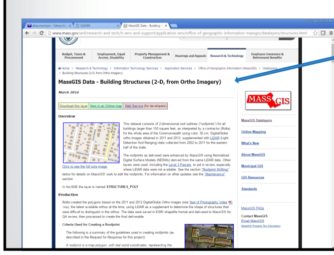
Download DEM from NED → Create Stream Network → Specify Return Interval (10-, 50-,100-, and 500- year) → Run Hydraulic Analysis

Developing Building Inventory

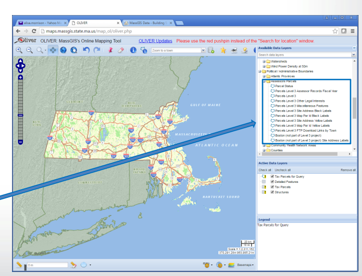
Site Specific Building Inventory

- HAZUS assumes that building exposure is distributed evenly throughout the census block
  - New mapping procedures in HAZUS 3.1 now remove undeveloped areas (water, wetlands, forests) from the blocks and more accurately distribute the building exposure.
- User-defined building inventory with actual building data should be used for most accurate assessment of potential damage

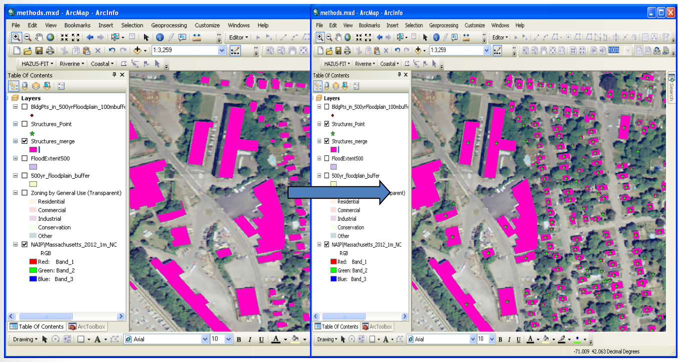


Building footprint shapefile (MA GIS)

Assessors Database (MA OLIVER)



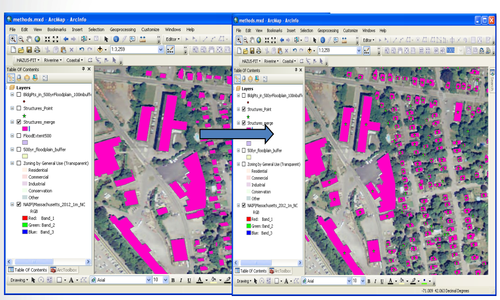
User Defined Inventory



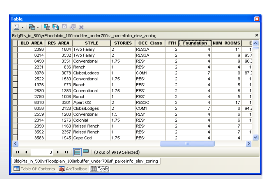
Create point locations of buildings within the floodplain.

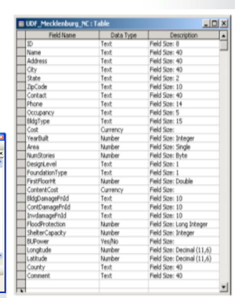
- Only primary structures are necessary. Exclude garages, sheds and small out-buildings
- Aerial photographs can be helpful in determining building use.

User Defined Inventory



- HAZUS needs several attributes for each building (i.e. location, occupancy, first floor height, # of stories, building value).
- The HAZUS Users Manual gives detailed instructions to import the user-specified inventory.

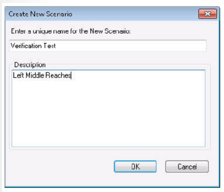


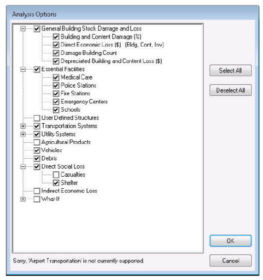


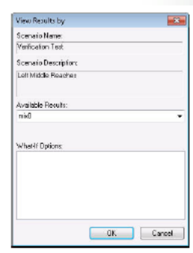
EPA

HAZUS Flood Module

Create Scenario → Run Analysis → View Results



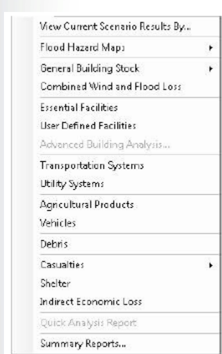


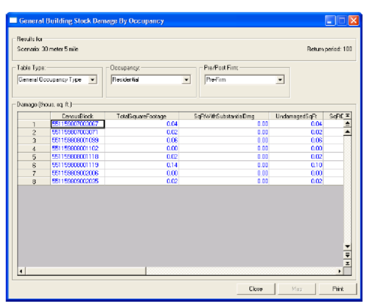


EPA

HAZUS Flood Module

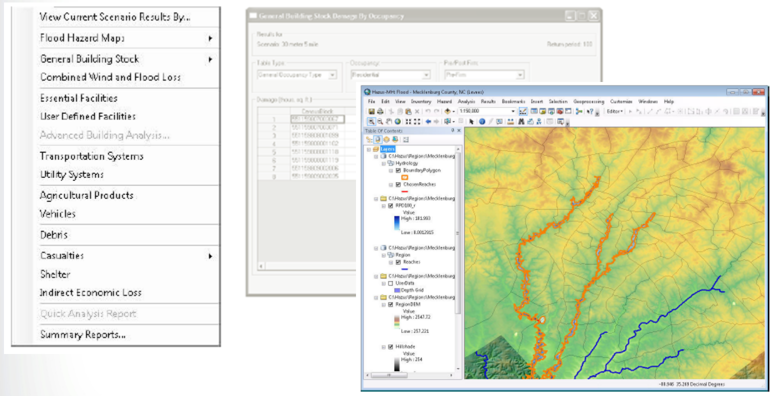
- **View Results - Tabular**





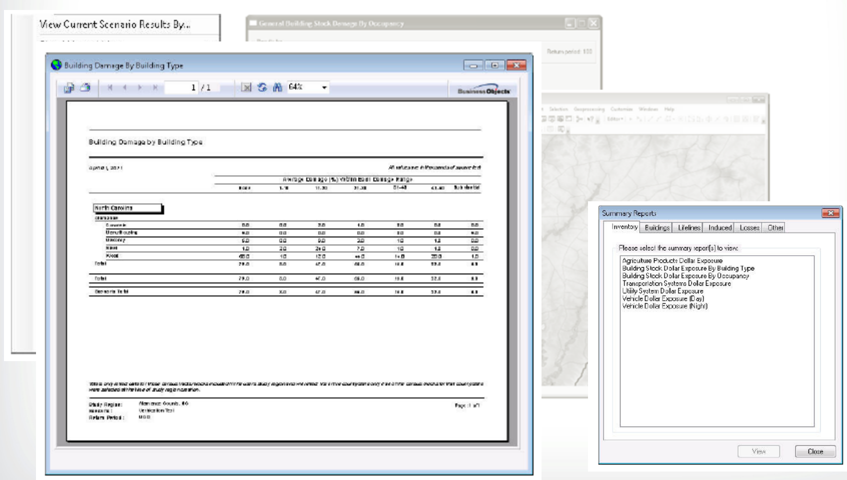
HAZUS Flood Module

- **View Results – Thematic Map**

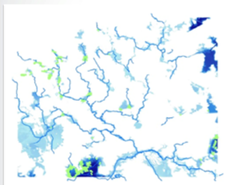


HAZUS Flood Module

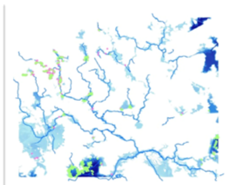
- **View Results – Summary Report**



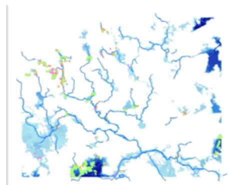
Example



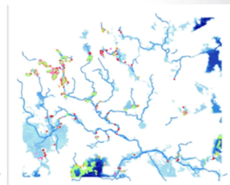
10 year flood



50 year flood

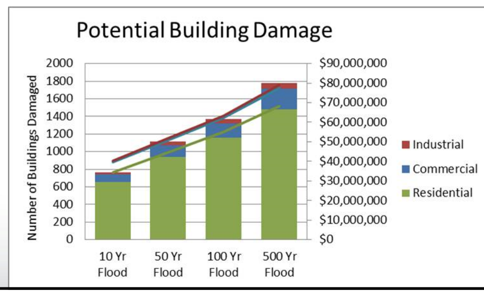


100 year flood



500 year flood

*To obtain damage curve, flood analysis needs to be run for multiple years. Handout shows method of using FEMA FIS maps to define flood grids for different flood levels.



Optimization Scenarios – Why? How?

Optimization Scenarios

- Uncertain about input data → run with multiple estimates
  - 20-year projected demand
  - +/-X%

3. Water use and demand management.

Enter the number of water use types but do not include unaccounted water; it is automatically included. Number of Water Use Types:

Press "Setup Input Tables" button to prepare appropriate sized input tables for potable and nonpotable demand and septic systems data based on number of water use types. *Setup Input Tables*

Navigate to each input tab associated with water use.

☐ Potable Demand ☐ Nonpotable Demand ☐ Demand Management ☐ Septic Systems

Potable Demand Return to Input

Enter data in blue input fields for available time period. Time series must be consecutive, e.g., days. For monthly time step, the day of the month does not matter.

Date	Total Water Demand [million gallons /time step]				
(mm/dd/yyyy)	Unaccounted	Residential	Commercial	Industrial	Municipal
1/1/2004	0.04	0.20	0.06	0.05	0.02
1/2/2004	0.04	0.20	0.06	0.05	0.02
1/3/2004	0.04	0.20	0.06	0.05	0.02
1/4/2004	0.04	0.20	0.06	0.05	0.02
1/5/2004	0.04	0.20	0.06	0.05	0.02
1/6/2004	0.04	0.20	0.06	0.05	0.02
1/7/2004	0.04	0.20	0.06	0.05	0.02
1/8/2004	0.04	0.20	0.06	0.05	0.02
1/9/2004	0.04	0.20	0.06	0.05	0.02

RUN OPTIMIZATION

Optimize

37

Optimization Scenarios

- Uncertain about input data → run with multiple estimates
  - Climate change – average, wettest, driest projections

1. Baseline Hydrology: Data for unmanaged land conditions.

A. Time series data:

Use Baseline Hydrology module for assisted data acquisition and entry **OR** manually enter your own data. Number of HRU types in your study area: 14

Press "Setup Baseline Hydrology" button to prepare baseline land use, runoff, and recharge input tables.

☐ Baseline Hydrology Module *Setup Baseline Hydrology* ☐ Runoff ☐ Recharge

Runoff Rates Time series of runoff rate from all HRUs for baseline condition and managed land use conditions.

Recharge Rates Time series of recharge rate from all HRUs for baseline condition and managed land use conditions.

Return to Input

Units: inches/time step

RUN OPTIMIZATION

Optimize

Date	Baseline HRU Set (HRU)												
(mm/dd/yyyy)	HRU1	HRU2	HRU3	HRU4			U7	HRU8	HRU9	HRU10	HRU11	HRU12	HRU13
1/1/2004	0.0004	0.0011	0.0012	0.00			0.0005	0.0014	0.0015	0.0024	0.0027	0.0030	0.002
1/2/2004	0.0003	0.0010	0.0011	0.0012	0.0014	0.0017	0.0004	0.0012	0.0013	0.0021	0.0024	0.0027	0.002
1/3/2004	0.0564	0.1598	0.1678	0.1786	0.1825	0.1845	0.0532	0.1506	0.1607	0.1769	0.1811	0.1840	0.175
1/4/2004	0.0616	0.1745	0.1838	0.1939	0.1982	0.1994	0.0606	0.1716	0.1838	0.1989	0.2022	0.2035	0.204
1/5/2004	0.0006	0.0018	0.0018	0.0017	0.0017	0.0019	0.0020	0.0055	0.0060	0.0056	0.0057	0.0055	0.008
1/6/2004	0.0005	0.0015	0.0015	0.0015	0.0015	0.0016	0.0013	0.0037	0.0040	0.0043	0.0044	0.0044	0.005

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Optimization Scenarios

- Uncertain about input data → run with multiple estimates
  - Bounding cases based on costs, run lowest and highest estimate

4. Water supply sources and infrastructure. Navigate to each input tab to enter data.

☐ Surface Water & Streamflow Targets ☐ Groundwater ☐ Interbasin Transfer ☐ Infrastructure

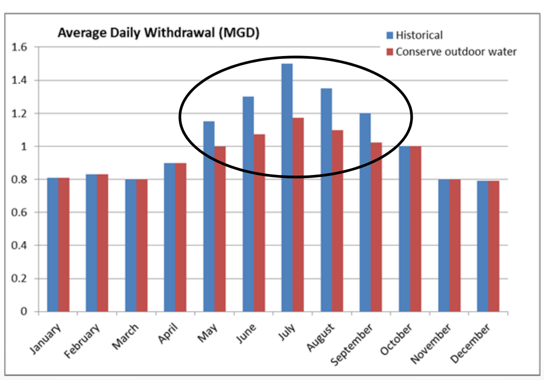
Aquifer Storage and Recovery (ASR)	Value	Units	Exclude New/Additional
Capital cost for additional/new capacity	10,807,824	$/MGD	
O&M costs	3,769	$/MG	
Existing maximum capacity	0	MGD	
Lifetime remaining on existing infrastructure	25	yrs	
Lifetime of new construction	35	yrs	

RUN OPTIMIZATION

Optimize

Optimization Scenarios

- Management action not pre-programmed in WMOST
  - Outdoor water conservation → change demand time series for summer months



Optimization Scenarios

- Cooperative agreement for water conservation with non-public water users → change "other" surface or groundwater withdrawals

4. Water supply sources and infrastructure. Navigate to each input tab to enter data.

☐ Surface Water & Streamflow Targets ☐ Groundwater ☐ Interbasin Transfer ☐ Infrastructure

Surface Water: Streamflow and Surface Storage Return to Input

cfs = cubic feet pe
O&M = operation

Initial reservoir/surface storage volume	230	[MG]
Minimum target reservoir/storage volume	230	[MG]
Existing maximum reservoir/storage volume	230	[MG]
Initial construction cost	0	[$/MG]
O&M costs	0	[$/MG]

-9
No

RUN OPTIMIZATION
Optimize

Date (mm/dd/yyyy)	Other Sw Withdrawal [MG/time step]	Other Sw Discharge [MG/time step]	External Sw Inflow [cfs]	Withdrawals from Reservoir [MG/time step]	Discharge to Reservoir [MG/time step]	Outflow from Reservoir [MG/time step]
1/1/2004	0.00	0.00	0.00	0.00	0.00	0.00
1/2/2004	0.00	0.00	0.00	0.00	0.00	0.00
1/3/2004	0.00	0.00	0.00	0.00	0.00	0.00
1/4/2004	0.00	0.00	0.00	0.00	0.00	0.00
1/5/2004	0.00	0.00	0.00	0.00	0.00	0.00

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Optimization Scenarios

- Determine maximum demand without iterative runs
  - high demand + expensive, interbasin transfer of water without limits

Interbasin Transfer (IBT) Return to Input

MG = million gallo
MGD = million gal

If you do not want IBT as a management option, enter -9 for costs AND 0 for flow limits.

Purchase cost for potable water	1,000,000	[$/MG]
Purchase cost for wastewater	-9	[$/MG]
Initial cost for new/increased IBT potable water limit	-9	[$/MGD]
Initial cost for new/increased IBT wastewater limit	-9	[$/MGD]

Enter existing limits on IBT for daily, monthly and/or annual basis. If flow is not limited, enter -9.

Month	Existing Limits on IBT [MG per month] Water	Wastewater
January	-9.00	0.00
February	-9.00	0.00
March	-9.00	0.00
April	-9.00	0.00
May	-9.00	0.00
June	-9.00	0.00
July	-9.00	0.00

Existing Limits on IBT	Water	Wastewater
Daily [MGD]	-9.00	0.00
Annual [MG per year]	-9.00	0.00

Additional Capacity Limits	Water	Wastewater
Daily [MGD]	0.00	0.00

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Optimization Scenarios

- Reservoir/lake – release operations and "sizing"
  - Invest in controlled release?
  - How much volume must be controlled?

Surface Water: Streamflow and Surface Storage

Return to Input

cfs = cubic feet per second
O&M = operations and maintenance

Initial reservoir/surface storage volume	200	[MG]
Minimum target reservoir/storage volume	190	[MG]
Existing maximum reservoir/storage volume	230	[MG]
Initial construction cost	100,000	[$/MG]
O&M costs	5,000	[$/MG]

	Exclude New/Additio
No	Enter *Yes* to use Rese

Month	*Minimum* In-Stream Flow [cfs]	*Maximum* In-stream flow [cfs]	*Minimum* Sw Outflow to External Sw [cfs]	*Maximum* Sw Outflow to External Sw [cfs]
January	-9.0	-9.0	2.7	-9.0
February	-9.0	-9.0	3.7	-9.0
March	-9.0	-9.0	4.4	-9.0
April	-9.0	-9.0	7.5	-9.0
May	-9.0	-9.0	4.0	-9.0
June	-9.0	-9.0	3.3	-9.0
July	-9.0	-9.0	1.7	-9.0
August	-9.0	-9.0	1.0	-9.0
September	-9.0	-9.0	0.6	-9.0
October	-9.0	-9.0	0.4	-9.0

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Optimization Scenarios

- Release operations only

Surface Water: Streamflow and Surface Storage

Return to Input

cfs = cubic feet per second
O&M = operations and maintenance

Initial reservoir/surface storage volume	200	[MG]
Minimum target reservoir/storage volume	190	[MG]
Existing maximum reservoir/storage volume	230	[MG]
Initial construction cost	-9	[$/MG]
O&M costs	-9	[$/MG]

-9	Exclude New/Additional tc
No	Enter *Yes* to use Reservoir/S

Month	*Minimum* In-Stream Flow [cfs]	*Maximum* In-stream flow [cfs]	*Minimum* Sw Outflow to External Sw [cfs]	*Maximum* Sw Outflow to External Sw [cfs]
January	-9.0	-9.0	2.7	-9.0
February	-9.0	-9.0	3.7	-9.0
March	-9.0	-9.0	4.4	-9.0
April	-9.0	-9.0	7.5	-9.0
May	-9.0	-9.0	4.0	-9.0
June	-9.0	-9.0	3.3	-9.0
July	-9.0	-9.0	1.7	-9.0
August	-9.0	-9.0	1.0	-9.0
September	-9.0	-9.0	0.6	-9.0
October	-9.0	-9.0	0.4	-9.0
November	-9.0	-9.0	0.3	-9.0
December	-9.0	-9.0	0.5	-9.0

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Optimization Scenarios

- Achieve specific release operations (i.e., sub-monthly targets)

Surface Water: Streamflow and Surface Storage Return to Input

cfs = cubic feet per second
O&M = operations and maintenance

Initial reservoir/surface storage volume	200	[MG]
Minimum target reservoir/storage volume	190	[MG]
Existing maximum reservoir/storage volume	230	[MG]
Initial construction cost	-9	[$/MG]
O&M costs	-9	[$/MG]

-9	**Exclude New/Additional** - to exc
Yes	**Enter *Yes* to use Reservoir/Sw O**

Date (mm/dd/yyyy)	Other Sw Withdrawal [MG/time step]	Other Sw Discharge [MG/time step]	External Sw Inflow [cfs]	Withdrawals from Reservoir [MG/time step]	Discharge to Reservoir [MG/time step]	Outflow from Reservoir [MG/time step]
1/1/2004	0.00	0.00	0.00	0.00	0.00	2.70
1/2/2004	0.00	0.00	0.00	0.00	0.00	3.70
1/3/2004	0.00	0.00	0.00	0.00	0.00	4.40
1/4/2004	0.00	0.00	0.00	0.00	0.00	7.50
1/5/2004	0.00	0.00	0.00	0.00	0.00	4.00
1/6/2004	0.00	0.00	0.00	0.00	0.00	3.30
1/7/2004	0.00	0.00	0.00	0.00	0.00	1.70
1/8/2004	0.00	0.00	0.00	0.00	0.00	1.00
1/9/2004	0.00	0.00	0.00	0.00	0.00	0.60

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Optimization Scenarios

- Change from septic to sewering
  - Septic (recharging inside & outside) = 0%
  - Interbasin transfer of wastewater excluded (i.e., 0 MGD limits, -9 costs)
  - Wastewater treatment plant
    - Capital cost = plant construction <u>and</u> sewering
    - Existing capacity = 0 MGD

Wastewater treatment plant (WWTP)	**Value**	**Units**	**Exclude New/Additional**
Consumer's price for wastewater services: Fixed fee	12,621.00	$/month	
Consumer's price for wastewater services: Variable, volume-based fee	5.00	$/HCF	
Are wastewater fees charged based on metered water or wastewater?	water	water or wastewater	
Capital cost for additional capacity	15,788,674	$/MGD	
O&M costs	7,925	$/MG	
Existing maximum capacity	0.00	MGD	
Lifetime remaining on existing infrastructure	0	years	
Lifetime of new construction	35	years	
Infiltration into wastewater collection system			
Existing Gw infiltration into collection system	0	% of WW Inflow	
Initial cost for survey & repair	0	$	
O&M costs for maintaining reduction in infiltration	0	$/yr	
Maximum percent of infiltration that can be fixed	0	%	

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Optimization Scenarios

- Important to know the sensitivity of results to input data and assumptions
- Actions most often part of the solution =
  - Most likely to be cost-effective actions

- Do NOT perform optimization and take the results as a prescription

→ WMOST is most appropriate for narrowing the decisions to those actions that are most likely to be cost-effective for meeting goals

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Optimization Scenarios

- Are there management options not readily available in WMOST that you would like to evaluate?

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Discussion

Discussion!

- What possibilities do you see for using WMOST to
  - support grant or loan applications?
  - manage multiple water-related problems?
  - inform or support permitting?

Examples of IWRM

- Massachusetts
  - Water Management Act, 2014
  - Gallon for gallon credit for stormwater recharge
- Great Bay, NH
  - Cost-savings in cooperative nitrogen reductions
- State of California
  - Integrated Regional Water Management Planning Act, 2002
- EPA
  - Integrated permitting for wastewater and stormwater, 2011
  - Kansas City, KS; Seattle and King County, WA; and Cincinnati, OH
- American Water Resources Association
  - Case Studies in Integrated Water Resources Management: From Local Stewardship to National Vision
  - 2 state-level (OR, CA); 3regional; 2scientifically complex

WMA 2014, UNH 2016, CA 2002, EPA 2011, AWRA 2012

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Considerations for Model Setup – Reconciling real world conditions with modeling options

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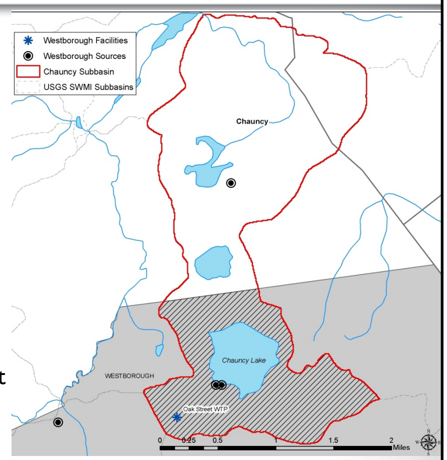
Model Setup

- **Spatial delineation**
- Subbasin boundary
  - WMOST model
  - Land use
    - →runoff/ recharge → stream/ aquifer
  - Lake or other surface storage
  - "Other" withdrawals/ discharges
- Intersections of town-subbasin boundary
  - Land available for conservation
  - Land available for stormwater management
- Town or town-subbasin boundary
  - Water and wastewater services



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Model Setup

- Demand / Water services
  - Subbasin "demand"
    - Specific fraction of total demand
    - Based on historic, projected or desired pumping from subbasin
  - Total town demand
    - Add interbasin transfer capacity = capacity of wells in other subbasins
- Wastewater
  - Septic, wastewater treatment plant and/or interbasin transfer
  - Must be for the users represented by specified demand

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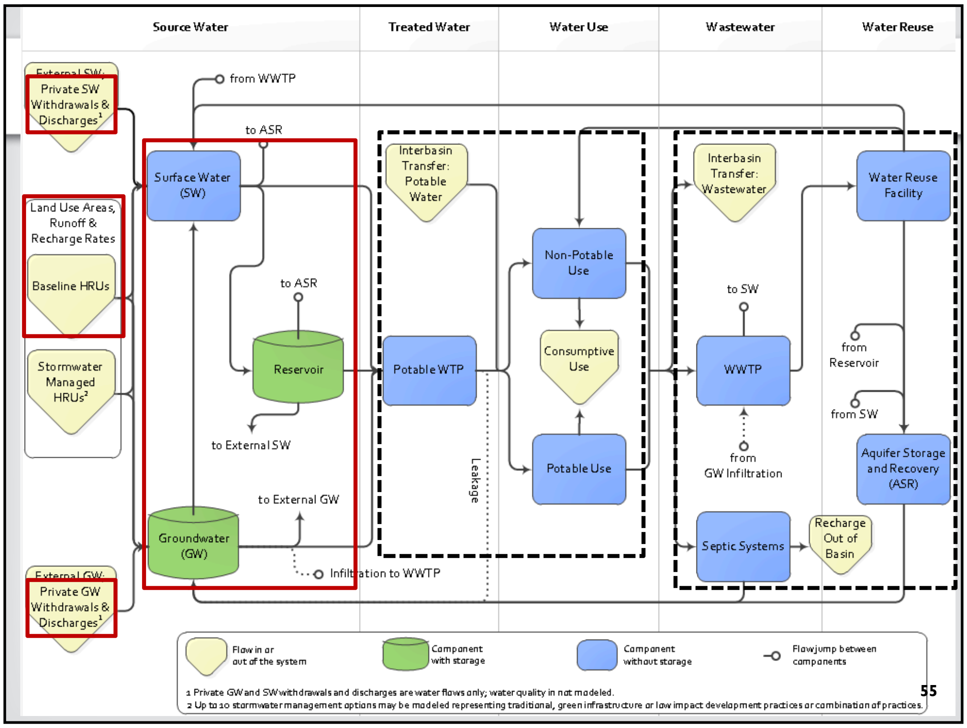

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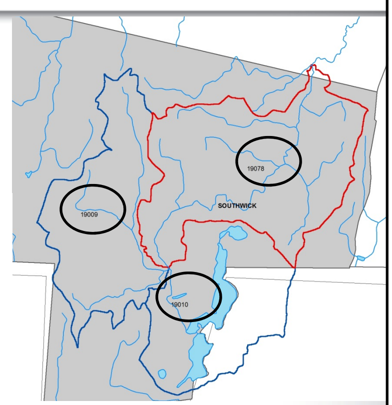
EPA

Model Setup

- Upstream watershed
  - External surface water inflow
  - (External groundwater inflow)



Groundwater Return to Input

Groundwater recession coefficient	0.08	[1/time step]
Initial groundwater volume	90	[MG]
Minimum volume	0	[MG]
Maximum volume	9,050,000	[MG]

Date [mm/dd/yyyy]	Other Gw Withdrawal [MG/time step]	Other Gw Discharge [MG/time step]	External Gw Inflow [MG/time step]
1/1/2004	0.00	0.10	0.00
1/2/2004	0.00	0.10	0.00
1/3/2004	0.00	0.10	0.00

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EPA

Model Setup

- More on surface waters
  - Water land use or reservoir/ surface storage
    - Subtract from "water land use" the area that is modeled as reservoir/ surface storage
  - Wetlands should be represented as land use

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EPA

Model Setup

- Value of land conservation for water resources
  - Projected or build-out land use

1. Baseline Hydrology: Data for unmanaged land conditions.
A. Time series data:
Use Baseline Hydrology module for assisted data acquisition and entry OR
Baseline Hydrology Module
B. Land Use: Enter HRU areas and costs for land conservation
Land Use

Zoned
Existing
Zoned

Baseline HRU Characteristics on

HRU ID	*HRU Name	Baseline A ea [acre]	Minimum rea [acre]	Maximum Area [acre]	Initial Cost to Conserve [$/acre]	O&M Cost [$/acre/yr]
HRU1B	Commercial-industrial-transportation, Sand and Gravel	29	20	29	-9	-9
HRU2B	High-density residential, Sand and Gravel	73	50	73	-9	-9
HRU3B	Medium-density residential, Sand and Gravel	141	100	141	-9	-9
HRU4B	Low-density residential, Sand and Gravel	111	80	111	-9	-9
HRU5B	Open, Sand and Gravel	200	100	497	100,000	5,000
HRU6B	Forest, Sand and Gravel	300	120	602	100,000	5,000

Based on zoning
Protected
Existing

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Model Setup

- Do regions in your area have unique setup needs?

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Calibration and Validation

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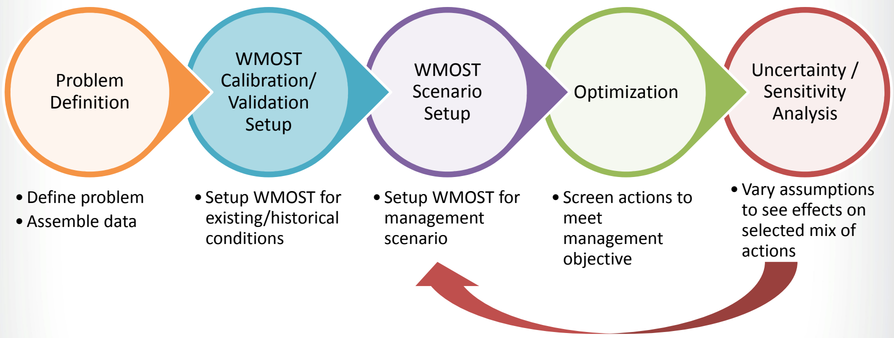
Calibration and Validation



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Calibration and Validation

- Calibration
  - Setup model for known conditions (for a portion of the measured flow record)
  - No management actions
  - No target streamflows or outflows
  - Adjust inputs and parameters as needed for good fit
- Validation
  - Run model for known conditions (for *another portion of* the measured flow recrod)
  - No management actions
  - No target streamflows or outflows
  - No further adjustments

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Calibration and Validation

- First, enter data on Step 6. Measured Flow

6. Measured streamflow. If available, enter measured streamflow data. ☐ Measured Flow

Date (mm/dd/yyyy)	Measured In-Stream Flow (cfs)
1/1/2004	13.10572612
1/2/2004	12.18367606
1/3/2004	12.05313184
1/4/2004	13.31186502
1/5/2004	14.0778813
1/6/2004	13.10219986
1/7/2004	10.93319524
1/8/2004	9.08598247
1/9/2004	6.866426514
1/10/2004	6.502315578
1/11/2004	6.651097102
1/12/2004	7.228234643
1/13/2004	7.452710922

Return to Input

cfs = cubic feet per second

Streamflow data sources:
- USGS or other agency flow gages
- Time series from a simulation model (e.g., HSPF)
- Others- see Data Sourced document on CD

- Second, optimize

RUN OPTIMIZATION

Optimize

- Third, view graph

Calibration and Validation

Intro Tab

ENTER INPUT DATA

Proceed to Input Data

RUN OPTIMIZATION

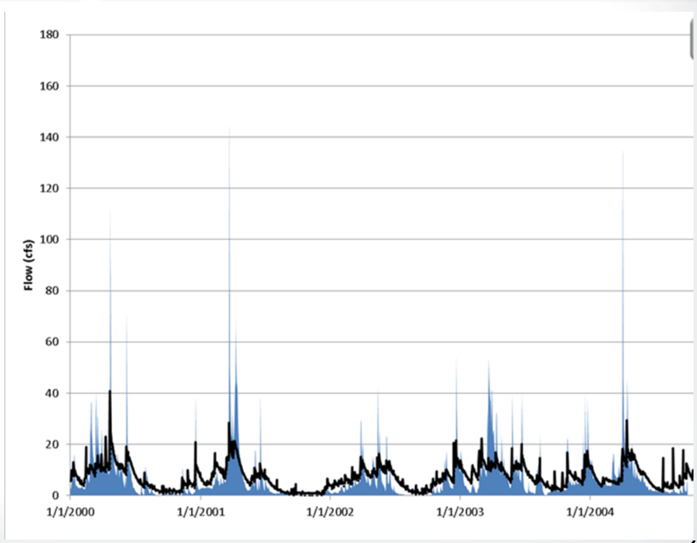
Optimize

EVALUTATE RESULTS

Results Table

Compare to Measured Flow

Compare to Target Flow



Evaluating "Goodness of Fit"

- Focus of management (Harmel et al 2014)
  - Low flow
  - High flow
  - Average flow
- Evaluation methods
  - Visual evaluation and patterns of fit (or lack of fit)
  - Statistics (Price et al 2012)
    - Flood peaks: Nash-Sutcliffe efficiency (NSE)
    - Lower flows: Modified Nash-Sutcliffe efficiency (MNS)
    - Flow variability: ratio of the simulated to observed standard deviations (RSD)
  - Statistics (Moriasi et al 2007)
    - For streamflow: NSE >0.50, ratio of the root mean square error to the standard deviation of measured data (RSR) <=0.70 and percent bias (PBIAS) +/- 25%

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Calibration and Validation

- Adjust inputs, focusing on most uncertain parameters and data
  - Change groundwater recession coefficient [groundwater tab]

Groundwater Return to Input

Initial KGw = 0.07

Groundwater recession coefficient	0.08	[1/time step]
Initial groundwater volume	90	[MG]
Minimum volume	0	[MG]
Maximum volume	9,050	[MG]

  - Apply multiplier to baseline runoff and/or recharge timeseries [runoff/recharge tabs]

Runoff Rates Return to Input

Time series of runoff rate from all HRUs for baseline condition and managed land use conditions.
Enter data in blue input fields for available time period. Time series must be consecutive, e.g., no skipped days. For mor

Units: inches/time step

Date (mm/dd/yyyy)	Baseline HRU Set (HRU) HRU1	HRU2	HRU3	HRU4	HRU5	HRU6	HRU7	HRU8	HRU9	HRU10	HRU11
1/1/2004	0	0	0	0	0	0	0	0	0	0	0
1/2/2004	0.03658	0.007839	0.004181	0.001306	5.22E-05	0	0.03658	0.007839	0.004181	0.001306	5.22E-05
1/3/2004	0.096333	0.020894	0.011418	0.003762	0.00045	0.000285	0.096565	0.02155	0.011897	0.003967	0.000568
1/4/2004	0.169928	0.03664	0.019633	0.006376	0.000537	0.000268	0.170324	0.037763	0.020797	0.006608	0.000846
1/5/2004	0.188638	0.040422	0.021559	0.006737	0.000269	0	0.188638	0.040424	0.02156	0.006737	0.00027
1/6/2004	0.028	0.006	0.0032	0.001	0.00004	0	0.028	0.006	0.0032	0.001	0.00004
1/7/2004	0	0	0	0	0	0	0	0	0	0	0
1/8/2004	0	0	0	0	0	0	0	0	0	0	0
1/9/2004	0	0	0	0	0	0	0	0	0	0	0
1/10/2004	0	0	0	0	0	0	0	0	0	0	0
1/11/2004	0	0	0	0	0	0	0	0	0	0	0
1/12/2004	0.028	0.006	0.0032	0.001	0.00004	0	0.028	0.006	0.0032	0.001	0.00004
1/13/2004	0.014	0.003	0.0016	0.0005	0.00002	0	0.014	0.003	0.0016	0.0005	0.00002
1/14/2004	0	0	0	0	0	0	0	0	0	0	0
1/15/2004	0.014	0.003	0.0016	0.0005	0.00002	0	0.014	0.003	0.0016	0.0005	0.00002

- Review your problem formulation

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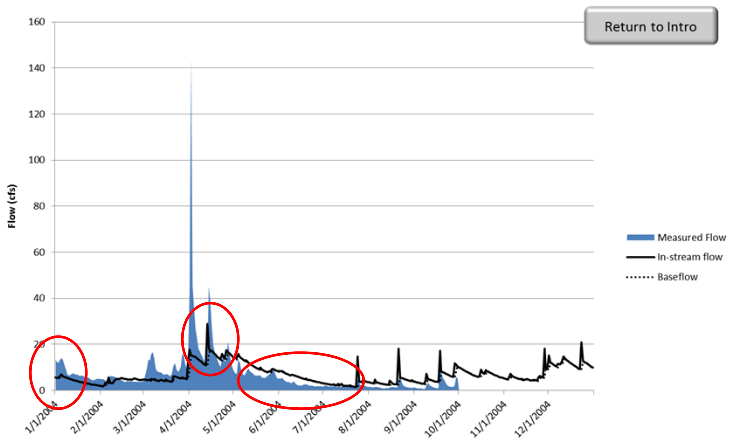
Calibration and Validation

Measured and Modeled Flows



Note: Baseflow may be higher than modeled in-stream flow. In-stream flow receives baseflow but also has withdrawals; therefore, final flow in the stream may be lower than baseflow.

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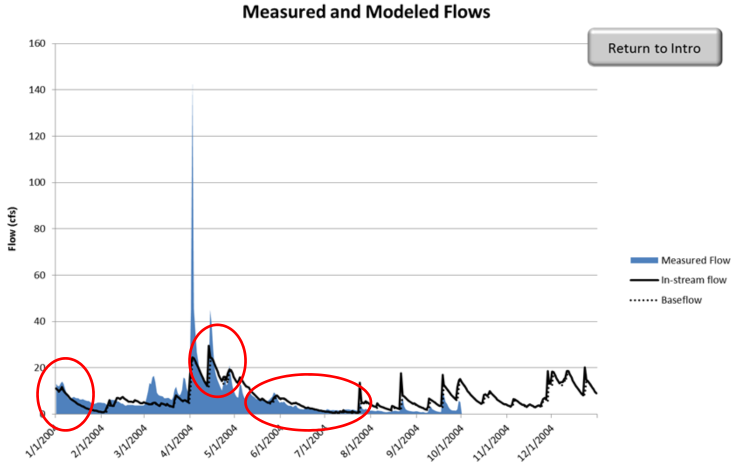
Calibration and Validation

Measured and Modeled Flows



Note: Baseflow may be higher than modeled in-stream flow. In-stream flow receives baseflow but also has withdrawals; therefore, final flow in the stream may be lower than baseflow.

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Calibration and Validation

- It's not working! I get "gazillion" dollars in annual costs and no other outputs… What's going on?
  - There is no feasible solution to your problem

Total Annual Cost	$1,000,000,000,000,000,000,000,000.0	million
Flood Damages	$0.0	million
Make-up Water Penalty	$0.0	million
Water Revenue	$0.0	million
Wastewater Revenue	$0.0	million

- Turn on the "make-up" surface water option on the Infrastructure tab
- Start with:
  - Low groundwater recession coefficient (e.g., 0.01) <u>*and*</u>
  - Adjust initial groundwater volume <u>*and*</u>
  - High maximum volume

Future Directions

EPA

WMOST Future Directions: 2016

- Water quality module(s)
- Combined sewer overflow module
- Climate change modules
  - Facilitate data import
  - Facilitate comparisons of climate change scenarios
- Expanded data availability
  - Regional coverage
  - Climate change scenarios
- Adding more case studies, user support

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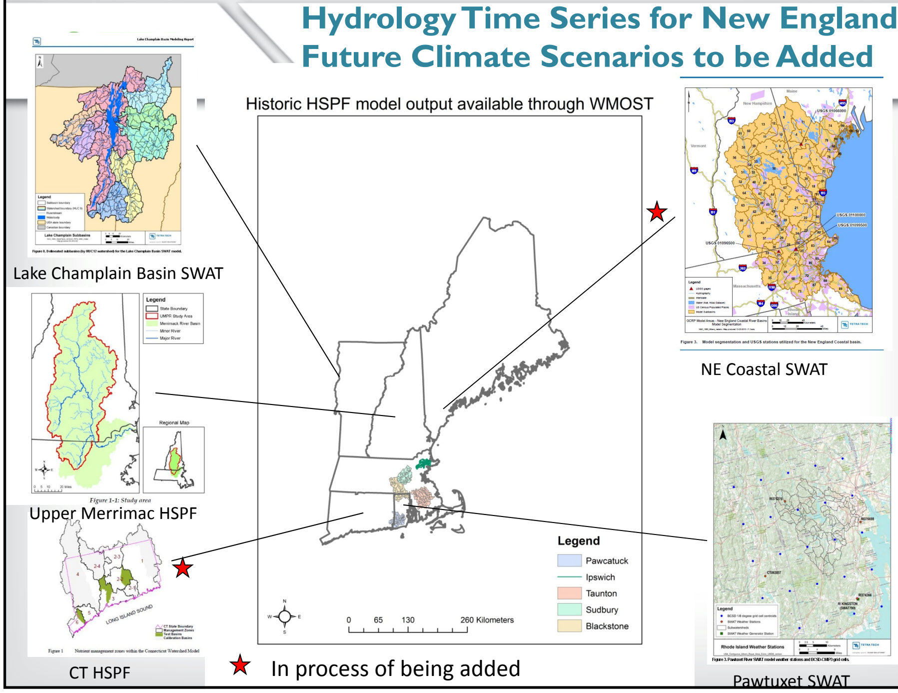
Hydrology Time Series for New England: Future Climate Scenarios to be Added

Historic HSPF model output available through WMOST



★ In process of being added

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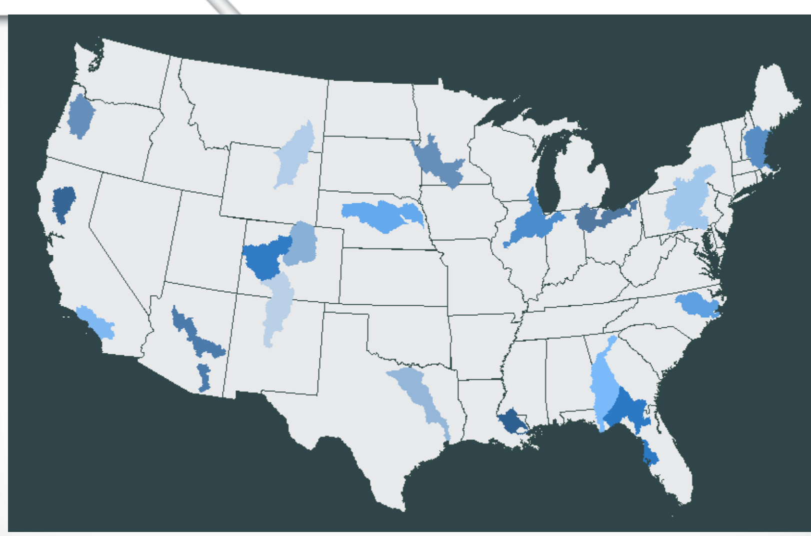
Hydrology Time Series: Chesapeake

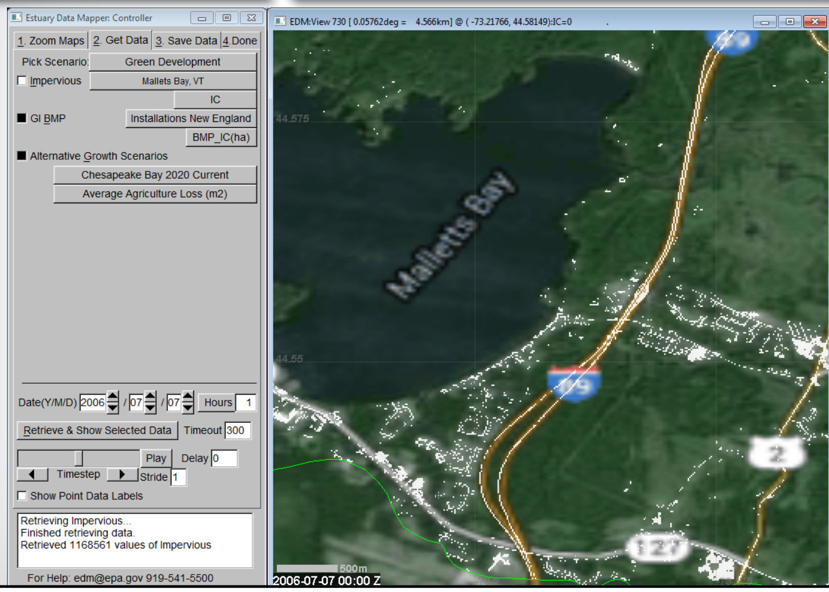
Section 1. Phase 5.3 Watershed Model Overview

Figure 1.6. Phase 5 domain and segmentation compared to Phase 4.3.

EPA 20 Watershed Study Additions: Historic and Future Climate Scenarios



Future Data Delivery



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Future Directions: 2017-2019

- More data
  - Automated import via internet (time series, HRUs by HUC12, …)
  - Both historic and future climate scenarios
  - Compatibility with nationwide models
    - HAWQS – SWAT model at HUC12 scale
    - USGS Monthly water balance model
- Robust decision-making modules
  - How do you plan for adaptive management in the face of uncertain climate futures?
- Green infrastructure co-benefits, e.g., health, energy savings
- Multi-objective decision making
  - How can you evaluate tradeoffs across multiple objectives?
- Scaling-up and linking watersheds
  - How can we scale up WMOST for larger watersheds and optimize across multiple watersheds?
- More case studies…

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Technical Support Discussion

- How can we best support communities and watershed organizations interested in using WMOST?
- What kinds of training would be most useful?
  - Face-to-face hands-on trainings: good venues?
  - Webinars: Full day or series of shorter presentations
  - Downloadable tutorials
  - Follow-up interactive training sessions
    - Problem formulation: How would I set up WMOST for this kind of problem?
    - Presentation/discussion of additional case studies
    - Trouble-shooting
    - Etc.
  - On-line "office hours" – submit your question ahead of time

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Community of Practice

- Would it be useful to develop a community of practice for people using WMOST?
- What features would be useful?
  - Email distribution list?
    - Distribute updates
    - Discussion of common problems/solutions
    - Post case study summaries
    - Help identifying useful data sources
    - Solicit case studies for EPA to assist with in testing new modules
  - Google group?
  - Quarterly training updates?
  - Other?

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Feedback -

Please fill out the short survey.

Thank you!

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